

Cambridge 5.
(1226).

J. F. Campbell Esq^r

From the Author

Lent to C. D. Walder

July 11 by ^{to be returned}

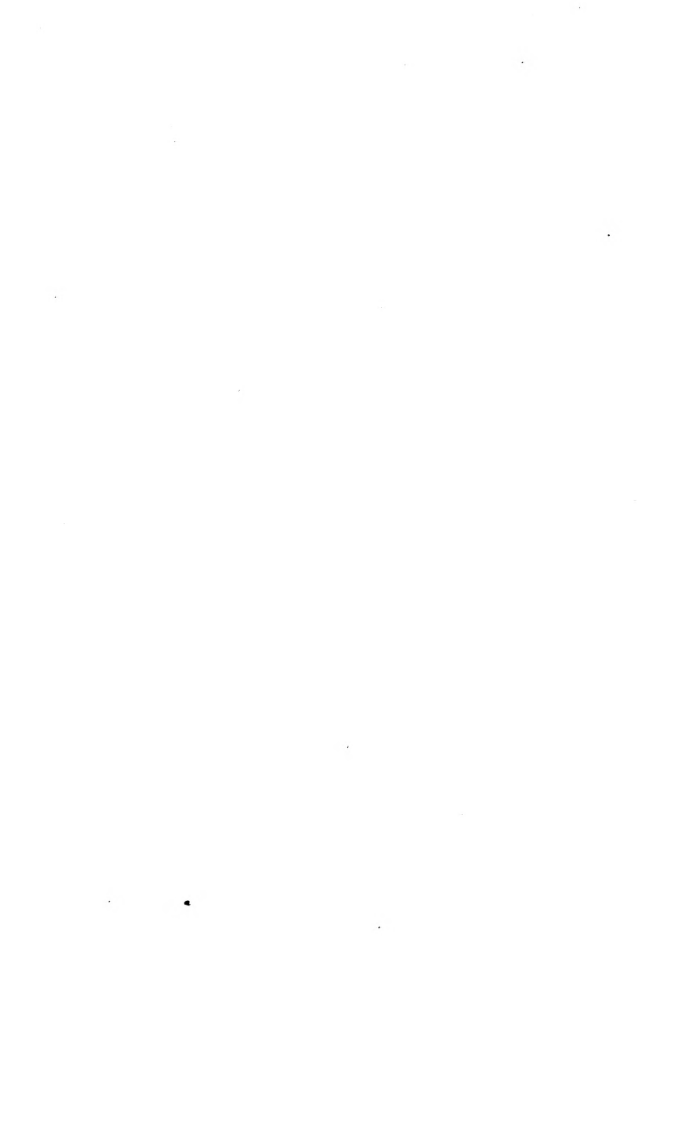
to J. F. Campbell Midway Lodge

Kensington.

If this view be correct coal
may be found ^{somewhere} near Cheswoldline
at a reasonable depth

See p. 181. for theoretical section
and 183. for map.

According to others the coal is
there but at enormous
depths.



On the EVIDENCES of a RIDGE of LOWER CARBONIFEROUS ROCKS crossing the PLAIN of CHESHIRE beneath the TRIAS, and forming the boundary between the PERMIAN ROCKS of the LANCASHIRE TYPE on the NORTH, and those of the SALOPIAN TYPE on the SOUTH. By EDWARD HULL, Esq. M.A., F.R.S., District Surveyor of the Geological Survey of Scotland.*

It has generally been supposed that the Triassic plain of Cheshire, almost encircled as it is by coal-fields, is itself a great repository of coal-bearing strata having few or no interruptions to its continuity, except towards the southern margin, where the Triassic and Permian rocks, overlying at intervals thin and marginal representatives of the coal-measures, approach the Cambrian and Silurian districts of Shropshire. I myself for a long while held and defended this view; nor was I aware until recently that it had ever been controverted. I am informed, however, by Mr. Jukes, that in a discourse which he delivered before the British Association in Birmingham, "On the Position and Extent of Coal-measures beneath the Red Rocks of the Midland Counties," in 1865, he expressed his opinion of the probability of ridges or bosses of rocks older than the coal-measures underlying the Trias of the plain of Cheshire and Salop, and throwing the Upper Carboniferous beds into detached coal-fields. These views were illustrated by large diagrammatic sections; unfortunately no report of this lecture is published in the Transactions of the Association.

With my own mind fully imbued with the idea of a continuous sheet of coal-measures stretching beneath the New Red Marl from the southern margin of the Lancashire coal-field as far south, at least, as the Lias of Prees, near Whitechurch †, I last winter (1867) was

* Communicated with the consent of the Director General.

† In this direction the old rocks which formed the original margin of the Carboniferous basin may be expected to occur in promontories projecting northwards under the Trias and Permian beds. (See Map, p. 183.)

engaged on a memoir for the Geological Survey on the Triassic and Permian rocks of the central counties; and it was when describing and comparing the Permian rocks of Lancashire with those of Shropshire and the midland counties that I was forcibly struck by the dissimilarity in structure and composition between the beds of these two tracts of England. I had, indeed, been aware of these differences previously, having passed several years in the survey of these rocks over parts of the central counties, Shropshire and Lancashire; but until I came to compare the Permian beds of these districts with each other on the occasion referred to, I had not perceived the full force of the fact that there are two types of beds, and two only, over the whole region from Warwickshire to Lancashire and Cumberland, and that the divisional line must lie somewhere in the region of the central plain of Cheshire.

Having arrived at this conclusion, it was natural I should seek for the cause of this dissimilarity between the Permian beds on the north and the south of the plain; and there were at first sight evidently three modes of explanation.

1. In the first place, it might be supposed that the whole of the beds were deposited contemporaneously in one continuous basin, and that the differences in mineral structure and composition arose from differences in the nature of the sediment brought down from opposite regions of land, and poured into the northern and southern portions of the basin respectively.

2. Or we might consider the beds of the two districts to be relatively of different ages, those of Lancashire and the north being more recent than those of Shropshire and the midland counties.

3. Or, lastly, we might suppose the beds of the two districts to be contemporaneous, but deposited in different basins, owing to the existence of a divisional ridge or barrier of the older rocks, such as is considered to have existed in the region of the Bristol Channel in the Devonian period. This is the only explanation which appears to me sufficient and tenable; and I venture to lay the reasons for this view before the Society in as concise a manner as the subject seems to admit of.

Before entering on this part of the inquiry, it will be necessary to present a brief description of the Permian rocks of the two districts, showing the distinctive characters of the two types I have referred to. But, in so doing, it is far from my intention to give a detailed description of the Permian districts of Central and Northern England, as ample accounts are already published, and to do so would therefore be but vain repetition. I shall therefore content myself with passing briefly in review the nature of the rocks as far as is necessary for my purpose, referring while so doing to the works of the eminent geologists who have written upon this branch of British geology.

PERMIAN BEDS OF THE SALOPIAN TYPE.

Distribution.—The general characters presented by the beds of

this type are those of a more or less local deposit, of which the marginal limits during deposition may in some places be traced. Towards the north-west, we first find these beds along the eastern boundary of the Denbighshire coal-field at Wrexham, and in the valley of the Dee, near Overton. South of the Severn, they reappear near Cardeston and Alberbury, where, with the remarkable calcareous breccia which there forms an important (but exceptional and local) feature*, they were originally described by Sir R. I. Murchison in the 'Silurian System.' We trace the same beds (with the omission of the calcareous rock, which disappears eastward) along the northern margin of the Le Botwood and Shrewsbury coal-fields, and again in greater force to the east of that of Coalbrook Dale. From this district they stretch southwards along the valley of the Severn, and in the district of Enville spread out over a large area, and are diversified by calcareous conglomerates and trappoid breccias, the origin of which has been referred by Professor Ramsay to the agency of ice. These beds were separated by the author in this district, as well as in that of Staffordshire, from the overlying Bunter Sandstone, and are described by Professor Ramsay in his memoir "On the Evidences of Permian Glaciers," published in the *Journal of the Society*†. The same beds reappear on both sides of the South Staffordshire coal-field, and are described in Mr. Jukes's memoir "On the Geology of the South Staffordshire Coal-field"‡. Crossing the Triassic district to the east of Birmingham, they are found to emerge from beneath the Keuper Sandstone and Marl, and to occupy a large tract of country lying to the west of the Warwickshire coal-field, where these beds were surveyed by Professor Ramsay and Mr. H. H. Howell, and are described by the latter in the *Memoirs of the Geological Survey*, "On the Geology of the Warwickshire Coal-field."

Along the west and the south of the Leicestershire coal-field we again find these beds, but in disconnected and attenuated masses, evidently the marginal representatives of the great formation of Warwickshire. In this district is clear evidence that we have reached the original limit of the lower Permian beds towards the north-east, and that we stand on the confines of the barrier of Carboniferous rocks which divided the Permian rocks of the North of England from those of the midland counties.

Along the southern and western margin of the North Staffordshire coal-field, the lower Permian beds again appear interposed between the coal-measures and the New Red Sandstone. When traced northwards for some distance, they are lost to view at Madely, partly through the overlapping of the Bunter Sandstone, partly through attenuation. Nor do we find any representatives of the

* This calcareous breccia is only, as Sir R. Murchison shows, a local deposit, derived for the most part from the disintegration of a limestone belonging to the upper coal-measures. It cannot be considered a representative of the Permian Limestones of the North of England.

† Vol. ii. p. 185.

‡ Mem. Geol. Survey.

Permian beds referable to the Salopian type to the north of this part of England, except in the case of the little outlier at Rushton Spencer, north of Leek, where they occupy a small area, and rest directly on Lower Carboniferous beds of the Yoredale series. Their occurrence at this spot was first pointed out by Mr. E. W. Binney*, and more recently by Mr. A. H. Green in the memoirs of the Geological Survey†. Both of these geologists concur in considering the beds to be of Permian age; and their position with reference to the Lower Carboniferous strata on which they rest is a point of interest and importance as bearing on the question concerning the extent of the denudation of the Carboniferous rocks before the Permian period in this locality, coincident, as it is, with the axis of elevation, to which I shall again refer, and which forms the special subject of our inquiry.

Mineral Characters of the Salopian Type of Permian Beds.—It may, I think, be safely affirmed that over the whole tract of country above described the Permian beds belong to the *Roth-todt-liegendes* or lower stage, and are all of one type—and this notwithstanding local and exceptional interpositions of peculiar beds deriving their origin from the agency of ice (as shown by Professor Ramsay in the case of the trappoid breccias), or on account of marginal conditions, as shown by Sir R. Murchison in the case of the Cardeston brecciated rock. With these and similar exceptions, the whole series (attaining a thickness of 1500 or 2000 feet in Warwickshire) consists of an assemblage of brown, red, or purple sandstones, often calcareous, alternating with red shales and marls, and characterized by much irregularity in the stratification. Both the sandstones and the local breccias and conglomerates are distinguishable from those of the Bunter Sandstone with which they usually come in contact; and the frequent interposition of beds of red marl gives the group a *facies* differing from that of any of the divisions of the Bunter Sandstone.

Such is the character of these beds, whether we find them in Denbighshire or Shropshire on the one side, or in Warwickshire on the other. They form a group of strata of themselves, differing in their mineral characters from the Permian rocks either of the North-west or North-east of England. Their original marginal limits may at intervals be traced both in Shropshire on the west, and in Leicestershire and North Staffordshire on the east, notwithstanding the obscurity occasioned by the overspreading of the Triassic formation. The beds at Rushton Spencer form, in my opinion, a marginal outlier, deposited in a hollow, along the line of the barrier of Lower Carboniferous rocks, which originally divided the beds belonging to the Salopian type from those of the Lancashire type.

* Memoirs of the Lit. and Phil. Society of Manchester, vol. xii.

† "Geology of Stockport, Macclesfield, &c.," by E. Hull and A. H. Green. The position of these beds is shown in a section by Mr. Green in our joint paper "On the Millstone Grit of north Staffordshire &c.," Quart. Journ. Geol. Soc. vol. xx. p. 260, fig. 7.

I now pass on to trace the characters and distribution of the Permian rocks of the latter type.

PERMIAN BEDS OF THE LANCASHIRE TYPE.

Distribution.—A fine exhibition of these beds may be observed along the banks of the Mersey, above Stockport, where they are interposed between the conglomerates of the Bunter Sandstone and the coal-measures of Cheshire. Passing towards the north and west, we find them opened out on a large scale at Collyhurst, near Manchester, where they were first identified as of Permian age by Mr. Binney*, as being clearly overlain by a series of marls with limestones containing fossils of Permian genera. From Manchester, they have been traced by the same geologist, along the southern margin of the Lancashire coal-field to Whiston, near St. Helens; and throughout they occupy a position of discordance, both as regards the Trias above and the coal-measures beneath. At Stockport the formation attains a thickness which I have estimated at 1500 feet. Whether or not it is so great, it is undoubtedly considerable; and had it not been for the superposition of the fossiliferous marls and limestones, which have been clearly determined to overlie this rock, by borings at Heaton Mersey, the whole (as far as lithological character is concerned) might have been regarded as of the Bunter Sandstone age.

Mineral Characters and Composition.—Instead of a series of interstratified sandstones, marls, breccias and conglomerates, such as that which forms the Lower Permian rocks of the Salopian type, we have in Cheshire and Lancashire a mass of homogeneous sandstone, resembling in every respect (except in position) the lowest division of the Bunter Sandstone of Shropshire and west Cheshire. This rock is generally so soft as to be used for foundry purposes, and consists of bright red and variegated sandstone, without pebbles, fine-grained, and traversed by planes of current-lamination.

When I first saw this rock in the quarry at Collyhurst, and judging only by mineral character, I thought I recognized in it the "Lower Mottled Sandstone" of the Bunter, with which I had been so familiar in Shropshire and west Cheshire; but the position of the fossiliferous marls which here overlie this sandstone, and which contain remains of the genera *Turbo*, *Rissoa*, *Natica*, *Gervillia*, *Avinus*, *Myoconcha*, and *Tragos*, determines beyond doubt the Permian age of the sandstone rock, as shown by Mr. Binney. It clearly forms a lower stage of the Permian formation in this part of England.

The contrast between these beds and their representatives in Shropshire and the midland counties is, in fact, as great as between the Bunter Sandstone and Permian beds of those counties.

The Upper Permian series of South Lancashire requires but short

* "On the Geology of Manchester," Trans. Geol. Soc. Manchester, vol. i.

notice here. All along the southern margin of the coal-field it consists of red calcareous marls and earthy limestones, with fossils of Permian genera, resting on the Lower Red Sandstone. At Leigh, west of Manchester, these beds have been proved by borings to reach 131 feet in thickness, with 52 courses of limestone; but their thickness in different localities is found to vary considerably, in proportion to the amount of overlapping of the Bunter Sandstone. At Stockport this overlapping is so great that the conglomerate beds of the Bunter rest directly on the Lower Permian Sandstone itself.

At Skillaw Clough, near Ormskirk, the occurrence of Magnesian Limestone in the upper member of the formation introduces a more typical feature into the succession of the beds, such as they present near Furness Abbey and Barrow Mouth, as described by Mr. Binney*, and enables us to recognize in them the representatives of the great calcareous formation of Durham, Yorkshire, and Notts. Mr. Kirkby, on palaeontological evidence, refers the upper member of the Permian series in South Lancashire to the "Lower Limestone" of Yorkshire†.

In the "Lower Sandstones" of Penrith, estimated by Professor Harkness to attain a thickness of 5000 feet‡, we have the apparent representative of the Lower Permian Sandstone of south Lancashire, but more fully developed in a northerly direction, as is usually the case with sandstone rocks of the Triassic and Permian ages in this part of England.

Durham, Yorkshire, and Nottinghamshire.—It is not within the scope of this paper to refer to the Permian formation of the North-east of England, except to point out the relationship of this series of beds to those of the midland counties and Lancashire, as far as regards original deposition. I will therefore only remark that, as regards their relations to the Lancashire series, though so different in mineral character, they really belong to the same type. Here we have the development of the calcareous member on the one hand, and of the sedimentary member on the other, being an illustration of the law of development, in opposite directions, of calcareous and sedimentary strata, which I believe may be observed in the case of all natural groups of rocks. And as it has been shown in a former paper that the elevation of the Carboniferous rocks along the meridional axis of the Pennine chain has taken place since the Permian period, there is every reason to suppose that the Permian beds, both on the North-west and North-east of England, were deposited within the limits of the same hydrographical basin, and that there was a gradual variation of mineral character taking place across the North of England. This view seems to be held by Mr. Kirkby with reference to the Upper Permian series§ in both districts.

* Mem. Lit. and Phil. Soc. Manchester, vol. xii. pp. 45, 46.

† Quart. Journ. Geol. Soc. vol. xvii. p. 320.

‡ *Ibid.* vol. xviii. p. 210.

§ Quart. Journ. Geol. Soc. vol. xvii. p. 321. Mr. Kirkby remarks, "The fauna of the Lancashire area appears to have existed on the argillaceous and semical-

On the other hand, the evidence which I am about to adduce seems to show that the Permian rocks both of the North-west and North-east of England were disconnected during their deposition from those of the midland counties and Shropshire. Under this view, it will be apparent that there are in reality only two types of Permian beds in England, those of the north and those of the midland counties; though at first sight it might have been supposed there were three, namely, those of the Salopian, Lancashire, and Durham or Yorkshire types.

POSSIBLE CAUSES OF THE TYPICAL DIFFERENCES IN THE PERMIAN FORMATIONS OVER THE SALOPIAN AND LANCASHIRE AREAS.

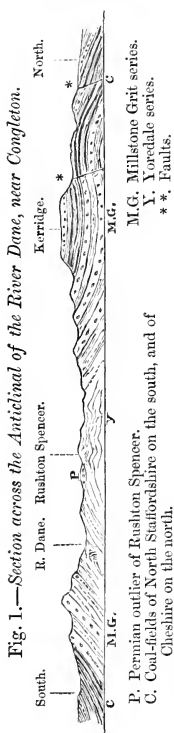
Having thus described the distinctive characters and range of the two types of Permian beds in the tract of country under investigation, it now remains to inquire into the causes of this diversity of character. As already stated, there appear to be three possible modes of explanation.

1. We might suppose that the beds of both types had been deposited in the same basin, and that the differences in mineral and stratigraphical character were due to differences in the sources of the sediment. This explanation appears to me insufficient, as there are no intercalations on either side. Considering the great thickness which this rock attains in North-east Cheshire (at least 1500 feet), and the proximity of the two districts, it is strange that it should not be represented by interstratification amongst the beds of North Staffordshire, if the two areas were in communication, or, on the other hand, that the beds of the Salopian type should not be represented by interstratification amongst those of the Stockport and Manchester district. This explanation also fails to account for the absence of the Upper Permian beds of Lancashire in the southern area, a series of beds which, from their very nature, may be presumed to have extended as far as the hydrographical boundaries would admit.

2. To suppose that the two types of rocks were not contemporaneous is still more unsatisfactory, and is not in accordance with the relations which the beds in both regions bear to the Carboniferous rocks on which they repose. These relations are precisely similar. In some places there is (as it were by accident) conformity, in others, great discordance. To suppose that there are two types of *Roth-todt-liegende* representing two successive stages of this earliest period of the Permian group, is not in accordance with observation in other districts. On the contrary, the beds of the Salopian type must, I think, be regarded as representatives in time of the Lower Red Sandstone of Lancashire, and both as representatives of the Lower Permian stage, or *Roth-todt-liegende* of Germany.

careous submarine mud-flats that lay off the coast of a Permian land-area; the Yorkshire fauna certainly existed further away in deeper water, and within the limits of regular deposition of calcareous sediment."

3. Dividing ridge of Lower Carboniferous Rocks (see fig. 2).



I now come to the explanation which seems to me the most probable, and one which is borne out by an examination of the physical geology of the North of England,—namely, the existence of a concealed ridge, or barrier, of Lower Carboniferous rocks, dividing the hydrographical areas belonging to the Lancastrian and Salopian types respectively, and the consequent deposition of the contemporaneous beds in two separate basins.

In a recent communication to this Society* I have shown that at the close of the Carboniferous period the Carboniferous beds of Lancashire were thrown into a series of folds, the axes of which range nearly east and west, and are parallel to, and continuous with, those which influence the same beds in Yorkshire as they approach and are lost beneath the Magnesian Limestone, as originally pointed out by Professor Phillips. This system of disturbances I ventured to call "the Pendle System," because it is well illustrated by the direction and flexures of the Pendle range of hills, running in an east-north-east direction. I also showed that there was a nearly parallel line of upheaval to the south of this range, passing along the valley of Rossendale, the direction of which is very nearly east and west; and to this I applied the term "Rossendale anticlinal."

When we proceed further south into the main coal-field of South Lancashire, we have no evidence of a repetition of these foldings (except, perhaps, as represented by a few east-and-west faults); but when, following the line of the Carboniferous rocks along

the margin of the plain of Cheshire, we arrive in the district bordering the valley of the river Dane, near Congleton—we again have evidence of a very powerful line of upheaval lying to the northward of Congleton Edge, and dividing the Cheshire coal-field from that of North Staffordshire. The general arrangement of the beds here will be better understood from the accompanying section, in which minor details are omitted (see fig. 1). The section is drawn from north to south in a line nearly parallel to the "Red-

* "On the Relative Ages of the Lading Physical Features and Lines of Elevation of the Carboniferous District of Lancashire and Yorkshire," Quart. Journ. Geol. Soc. vol. xxiv. p. 323.

rock fault," along which the Triassic rocks are brought in on the west.

It will be observed that along this anticlinal the lower beds of the Yoredale group, immediately overlying the Mountain Limestone, are brought to the surface, this latter rock itself being found at Astbury, at the base of Congleton Edge, but not in the line of the section*.

As regards the age of this anticlinal, we are, fortunately for our purpose, not left in doubt. Not far to the eastward is the Permian outlier of Hug Bridge, near Rushton Spencer, where, as already stated, sandstones and marls of Permian age rest immediately on the Yoredale beds. We have here, therefore, an illustration, similar to that of Clitheroc, in North Lancashire, of disturbances accompanied by enormous denudation of the Carboniferous rocks at the close of the Carboniferous period, and antecedently to that of the Permian. The amount of denudation in this instance may be thus estimated†:—

		feet.
Coal-measures.....	{ Upper	1000
	{ Middle	4000
	{ Lower	1000
Millstone Grit.....	Several divisions.....	1000
Yoredale Series (in part).	Several divisions	2000
		<hr/> 9000

The easterly prolongation of the anticlinal of the river Dane cannot be very clearly traced, owing to the rearrangement of the Carboniferous beds along the lines of disturbance in a meridional direction (north to south) at the close of the Permian period. As already shown on a former occasion‡, the series of foldings along axes ranging from west to east into which the Carboniferous rocks of the North of England were thrown at the close of the Carboniferous period have been modified by two subsequent lines of disturbance at the close of the Permian and Jurassic periods respectively; but the whole three systems bear a close physical relationship in time and direction to each other. In the district bordering the Mountain Limestone of Derbyshire the intersection of these lines of disturbance, accompanied and followed, as they have been, by several denudations, have complicated the structure of the rocks as it originally existed at the beginning of the Permian period. Hence the difficulty of following out the course of the anticlinal of the Dane eastward; nevertheless it may, I think, evidently be traced

* A detailed description of the beds in this district will be found in "The Geology of the Country around Stockport," &c., by Messrs. Hull and Green Mem. Geol. Survey, pp. 69-74.

† The thickness of the Coal-measures is that ascertained by the Geological Survey as applying to North Staffordshire, which is less than that of Lancashire. The thickness of the Millstone Grit and Yoredale beds is that given in the Memoir, on "the Geology of Macclesfield," &c., above quoted (see p. 85). The above estimates are probably rather under than over the truth.

‡ "On the relative Ages of the Physical Features," &c., *suprà cit.*

along the course of the Yoredale beds to the north of the Cheadle coal-field, and across the Mountain-Limestone country by Meerbrook and Butterton, in the direction of Matlock, while a branch stretched more to the southward in the direction of Charnwood Forest.

I cannot, therefore, but regard the anticlinal fold which separates the coal-fields of North Staffordshire and Cheadle on the south from those of Poynton and Goldsitch Moss on the north as belonging to the Pendle system of disturbances, ranging nearly from west to east, and, by the position of the Permian beds at Rushton Spencer, clearly shown to have originated at the close of the Carboniferous period. If such be the case, can it be doubted that the anticlinal extends *westward* under the Triassic rocks of Cheshire?

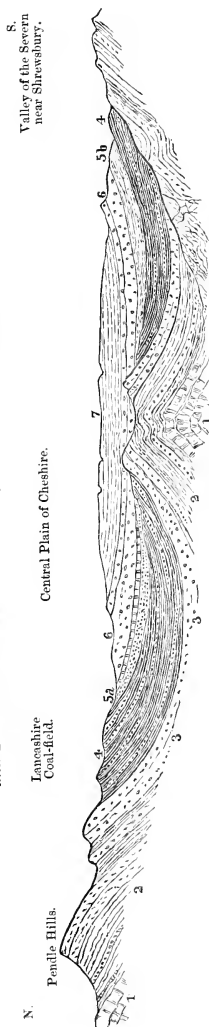
If, therefore, as appears to be the case, the Dane anticlinal stretches westward under the Triassic plain, we may reasonably look for some evidence of its continuance and reappearance on the western margin of the plain where the Carboniferous beds emerge from beneath the New Red Sandstone. This evidence, I think, we can find.

The Carboniferous Anticlinal in North Wales.—If the Geological Map be referred to, it will be observed that at its southern extremity the Flintshire coal-field is completely dis severed from that of Denbighshire by the uprising of the Lower Carboniferous rocks, from which the coal-measures have been denuded.

The age of this fault, belonging probably to several periods of vertical movement, is, at least, clearly *præ*-Triassic, as it disappears beneath the New Red Sandstone near Hope without producing any displacement of the beds; and it is also post-Carboniferous. Its relation to the Permian beds cannot be determined by observation, as it is nowhere brought into contact with them. It seems, indeed, to be gradually dying out towards the east as it approaches the New Red Sandstone, and to pass into an anticlinal axis. The view which I venture to offer is this:—I regard this upheaval as belonging to the Pendle system of disturbances at the close of the Carboniferous period, as indicated by the parallelism of its direction to this system, and also as being continuous in direction with the Dane anticlinal axis on the eastern borders of the Cheshire plain.

Supposed Structure of the Carboniferous Rocks under the Cheshire Plain.—If the above reasoning be admitted, it follows that there exists under the Triassic rocks of Cheshire an axis of elevation of Lower Carboniferous beds ranging from the southern borders of the Flintshire coal-field near Hope, on the west, to the valley of the Dane, north of Congleton, on the east, dividing the coal-field, which we may conclude originally spread uninterruptedly over the whole area, into two portions, to the north and south of this axis. I do not pretend to much precision in describing the course and structure of this axis under a tract of newer rocks 35 miles in width: it is probably accompanied by more than one parallel folding of the beds; but I think, with the arrangement of the rocks at Congleton Edge and the Roaches near Leek before us, we might venture to idealize the structure of this axis and its relations to the newer formations

Fig. 2.—*Diagrammatic Section, to illustrate the position of the supposed axis of elevation, and its relations to the Triassic and Permian Rocks under the Plain of Cheshire. (Details omitted.)*



1. Carboniferous Limestone near Clitheroe, and along the axis of the supposed ridge under the Cheshire Plain.
2. Yoredale series, cropping out along the flanks of the Pendle Range, and, along with the Millstone Grit, becoming attenuated southwards, and terminating against the shelving flanks of the Silurian rocks in Shropshire (on the right-hand side of the woodcut).
3. Millstone-Grit series.
4. Coal-measures of the South-Lancashire Coal-field, dipping under the Permian and Triassic rocks of Cheshire, then flattening and rising towards the south, and discovered from the Coal-measures of Shropshire by the supposed axis of elevation.

- 5 a. Permian series of the Lancashire type, resting discordantly on the Carboniferous rocks, consisting of red marls with limestone in the upper series, and of soft red sandstone in the lower.
- 5 b. Permian series of the Salopian type, separated from the Lancashire beds by the ridges of Carboniferous rocks, and consisting of purple sandstones and marls, breccia and conglomerates, &c.
6. Bunter Sandstone, becoming thinner towards the south and on approaching the Palaeozoic axis.
7. Keuper Marls and Sandstone of the Central Plain of Cheshire.

somewhat as shown in the accompanying section (fig. 2; see also map, page 183).

The Coal-measures on each side of the supposed Axis.—As there is no evidence of any similar axis, we may suppose that the coal-field extends from the northern flank of the Cheshire axis to the borders of the Lancashire Coal-field on the north, which, with that of Flintshire on the west and Poynton on the east, must form one continuous sheet (see map). To the south of the axis the coal-measures may also be supposed to stretch for a considerable distance, and to be continuous with those of Denbighshire and North Staffordshire. The southern limits of this coal-tract are in all probability very irregular and indented, owing to the proximity of the ancient margin of the Carboniferous area. Should the plains of Mid-Cheshire ever be pierced in search of coal, which from the enormous thickness of the overlying secondary rocks appears hopeless, care will be required to avoid striking upon the rocks below the coal, in the line of the anticlinal axis and along the southern margin, indicated by the lighter shading on the map.

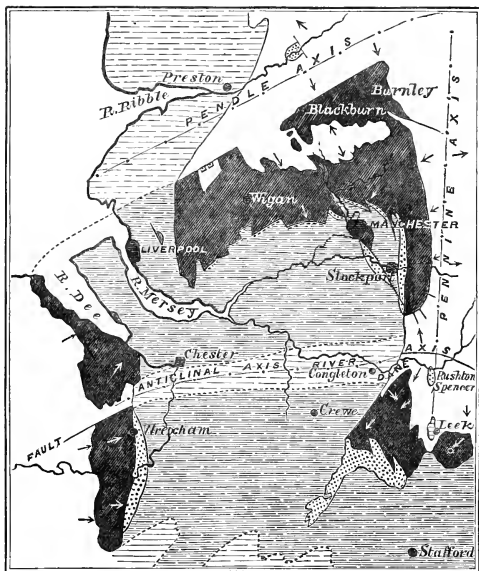
The Permian Beds on each side of the supposed Axis.—The existence of such an axis of elevation as is here indicated, formed at the close of the Carboniferous period, and belonging to the "Pendle system" of flexures, serves, I think, to explain the difference in the character of the Permian formation to the north and to the south of such a line in a more satisfactory manner than any other hypothesis. The elevation of the Lower Carboniferous rocks into ridges, from which the coal-measures were swept away partly by atmospheric, partly by marine, denudation, would produce a ridge, or ridges, of land-surface dividing the Permian basin on the north from that on the south. That the Carboniferous rocks *were* thrown into such ridges flanking the Permian sea, is clear from the position of the beds at the northern base of the Pendle range at Clitheroe. To admit of this hypothesis, we are not required to adopt a speculation which has no example in this part of the country; while it helps to solve the problem why the Permian beds on either side of this ridge belong to two distinct types, the Salopian and the Lancastrian.

CONCLUSION.

In conclusion, I regard the axis under the Cheshire plain as merely the prolongation of the Carboniferous barrier which separated the Permian basin of the north of England from that of the Midland counties and Shropshire. The barrier was apparently prolonged towards the district of Charnwood Forest, where it was composed of Cambrian rocks, and was formed for the most part of Mountain Limestone, Yoredale beds, and Millstone Grit, on either side of the barrier. The Permian formation itself gives evidence of the proximity of land; for on the north side the Magnesian Limestone becomes deteriorated both in composition and thickness towards Nottingham, and on the other the Permian beds along the skirts of the Leicestershire Coal-field are evidently marginal representatives

of the great formation of Warwickshire. To the north and to the south of this barrier the Permian formation exists under two distinct phases or types of character; and the occurrence of such a dividing ridge as I have indicated seems to offer the most satisfactory explanation of these differences in composition and arrangement.

Fig. 3.—Sketch Map of part of Lancashire, Cheshire, and Shropshire, showing the position of the concealed ridge of Lower Carboniferous Rock, or anticlinal axis, and of the Coal-measures to the north and south of the axis. By Edward Hull, F.R.S.



Coal-measures
at the surface.



Permian Beds.



Triassic Beds
overlying
Coal-measures.



Triassic Beds
resting on strata
older than the
productive
Coal-measures.

EXPLANATION OF MAP.

This Map is intended to show the position of the existing Coal-

fields round the margin of the Triassic plain of Cheshire, and the extension of the Coal-measures below the Triassic and Permian rocks of the plain. The position of the axis of Lower Carboniferous rocks from west to east is represented by the unshaded band ranging under the banded portion (representing the Trias and Permian area), and emerging at each side in the tract now formed of Lower Carboniferous beds in North Wales and East Cheshire. The shaded portion banded with close lines shows the extent of the Coal-measures to the north and south of the axis covered by Permian and Triassic formations; and it will be observed that the whole Coal-tract, both at the surface and concealed, resolves itself into two great coal-fields to the north and to the south of the supposed barrier of Lower Carboniferous rocks, that to the north being continuous with the Coal-fields of Flintshire, Lancashire, and Cheshire, that to the south with the Coal-fields of Denbighshire and North Staffordshire. A southerly prolongation of this tract probably connects it with the Shrewsbury Coal-field.

It will be observed that at the northern part of the map, and extending inland for some distance from the coast of Lancashire, there is a large banded tract of ground covered by Triassic rocks, under which, if penetrated, I consider that only the Lower Carboniferous beds (below the coal) would be found, the whole of the Coal-measures having been removed by denudation before the Permian period. To this tract I have referred in my paper on the relative ages of the physical features and lines of elevation of Lancashire (*Quart. Journ. Geol. Soc.* vol. xxiv. p. 333).

DISCUSSION.

Prof. RAMSAY considered that the lithological differences in the Permian rocks of the two areas referred to were hardly so great as was supposed by Mr. Hull.

Mr. PRESTWICH remarked that the nearly equal thickness of the Permian deposits in the two areas was in favour of their having been deposited in continuity.

Mr. W. W. SMYTH considered that the difference between the Permian beds in question was not so great as the author supposed but that the undoubted existence south of Chester of a breadth of 5 or 6 miles of Bunter Sandstone lying immediately upon the Millstone Grit, although observed only at one point, was strongly in favour of the author's hypothesis.

Mr. HULL stated in reply that the difference between the two groups of Permian rocks to which he had referred was so great as to render their identity at first sight very doubtful. The extent of the anticlinal at Rushton Spencer is so great that it must be inferred to have extended far both to the east and west.

